pound ointment of potassic iodide to be thoroughly rubbed in over the callous scar. The boy remained under my care during four months, and was entirely relieved of the nictitation as soon as the callous disappeared, although once during that time he had a short relapse, due to the irritation of an intervening conjunctivitis, as the following notes of record may show:—

Feb. 22. Infiltration about the cicatrix reduced to the size of a dime. Nictitation markedly diminished.

March 15. Since yesterday lids have been acting worse again; callous infiltration is all gone; scar is soft and movable, but conjunctiva of lids is very red; papillæ of upper lids slightly swollen; patient says it feels as though there is some grit under the lids. Ordered solution of sulphate of zinc.

April 5. Lids do not wink any oftener than normal; conjunctivitis cured.

May 15. No change since last visit.

In these and similar cases, I think, the operation of nerve-stretching could be performed with success if the medicinal applications had not the desired effect.

ARTICLE VIII.

THE PATHS OF CONDUCTION OF SENSORY AND MOTOR IMPULSES IN THE CERVICAL SEGMENT OF THE SPINAL CORD.

By ISAAC OTT, M.D., and ROBERT MEADE SMITH, A.M., M.D., Demonstrator of Experimental Physiology in the University of Pennsylvania.

FROM the time when Alexander Walker in 1809 first formed an hypothesis as to the different functions of the columns of the spinal cord no point in the physiology of the nervous system has been more assiduously studied than the paths of conduction in the cord, and yet in no other subject are the views of investigators more unsatisfactory and conflicting. Apart from the intrinsic difficulty of the subject there is no doubt that while many of the discrepancies are to be explained as owing to the study of different regions of the cord in different species of animals, the main source of error must be attributed to a faulty mode of operation. In the old method of free hand section employed by Brown-Séquard, Schiff, and Longet to whom we owe the most generally accepted views on this subject, the portions of the cord which it was desired to retain intact could scarcely avoid being dragged or pressed upon with a necessary consequence of a disturbance of their function and a complication of the results of the operation. The defects of this mode of procedure have been largely removed by the invention of a special instrument by Dr. Woroschiloff, by means of which any portion of the cord can be accurately isolated and divided without the remaining portion being at all contused or dragged upon in the operation. (For description and illustrations of the apparatus see Woroschiloff, *Ludwig's Arbeiten*, 1874, and Cyon, *Methodik der Physiologischen Experimente u. Vivisectionen*, p. 525.)

Method.—In all our experiments rabbits were used and our investigations only extended to the cervical region. The animals were fastened on Czermak's holder with the head strongly flexed on the neck; after dividing the skin and muscles by a longitudinal incision and hooking back the muscles by weighted cords, the bony vertebral column was trephined over the second or fourth cervical vertebra and the wound carefully enlarged with sharp cutting bone forceps. When bleeding occurred it was checked by bovista and cotton, sometimes aided by artificial respiration. After making whatever division of the cord that was desired, by means of Woroschiloff's instrument, and carefully closing the wound, the animal was allowed to rest in a warm place for about five hours, by which time the shock had entirely passed off, and the degree of sensibility and voluntary motor power remaining in the different limbs tested.

To test sensibility, the extremities were pinched or irritated by an electric current, or occasionally touched with a hot wire, and if the animal moved its head it was inferred that sensory fibres still existed in the undivided part of the cord; if upon pinching the ears movements were produced in the posterior extremities, the conclusion was reached that all the motor fibres were not divided. After having satisfied ourselves as to the degree of sensibility and voluntary motor power remaining, the cord was divided immediately below the medulla, and artificial respiration kept up. The distal segment of the cervical cord was then irritated with a weak induction current from a Valentin apparatus, and since Woroschiloff has shown that in the cervical cord there appears to be a centre which, when irritated, causes co-ordinated movements in the hind limbs, the movements resulting after such irritation in a rabbit with a partially divided cord, were noted as additional evidence as to the number of motor filaments remaining undivided. In all our experiments the results thus obtained agreed with the conclusions drawn from the degree of motion manifested by irritating the ears, nose, etc. The animal was then killed by stopping the artificial respiration, and the segment of the vertebral column containing the portion of the cord that had been operated on cut out and placed for two days in alcohol; the cord was taken out and freed from its membranes and placed for another day in alcohol, and then transferred to a two per cent. solution of bichromate of ammonium. After hardening the cord was imbedded in paraffine, and sections made in a microtome. The sections showing under the microscope the most extensive division of the cord, were selected as indicating the degree of division accomplished in the operation; they were then suitably mounted and drawn. The sections with one or two exceptions were made above the origin of the nerves, going to the anterior extremities; in the rabbit these nerves arise from the fourth, fifth, sixth, seventh, and eighth pairs of cervical nerves, and first dorsal.

Posterior columns.—The posterior columns have been believed to preside over movements of extension (Bellingeri, Valentin); over movements of flexion (Budge, Harless, Englehardt); both over movement and sensibility (Meckel, Schœps, Rolando, Calmiel, Jobert); exclusively over sensibility (Bell, Backer, J. Müller, Longet); exclusively over movement (Walker); more over sensibility than movement (Magendie, Seubert); and over anti-peristaltic contractions of the abdominal viscera (Valentin). When associated with gray matter they were supposed to conduct sensation by Fodera, and both sensation and motor impulses by Van Deen and Kürschner. The posterior columns are supposed by Schiff to conduct tactile sensations, and by Todd and Vulpian to be concerned in muscular co-ordination. Several observers (Fodera, Bellingeri, Calmeil, Vulpian, Philipeaux, Brown-Séquard) have stated that division of the posterior columns is followed by hyperæsthesia in the posterior extremities; that after section of one posterior column there is hyperæsthesia on the side of section and anæsthesia on the opposite side (Brown-Séquard, Vulpian), and that hyperæsthesia may be produced by irritation of one posterior column (Vulpian). In our experiments, division of the posterior columns *alone* was followed by no effect but disturbance of muscular co-ordination, more marked when both columns and a portion of gray matter are divided, which gradually passed off in one or two days. No appreciable disturbance of sensation ever occurred. If, however, the section extended through the gray matter then hyperæsthesia occurred, and when the section is made so as to include a small portion of the lateral column, then both loss of sensation and motor power occurred, thus showing that in previous experiments in which these results had been said to follow section of the posterior columns alone, either the neighbouring parts of the cord had been injured in the operation or the division was not accurately confined to the posterior columns.

Expt. 30.—Very large rabbit: etherized; tracheotomy. Section of both posterior columns under the second cervical vertebra (Fig. 1) at 11.15 A.M., without hemorrhage; no interference with respiration. 4 P. M., muscular inco-ordination; no paralysis, anæsthesia, or loss of tactile sensibility; no hyperæsthesia. Next day inco-ordination less marked, condition otherwise unchanged.

Expt. 16.—Small rabbit: etherized; tracheotomy. Section of right posterior column extending into the gray matter under the second cervical vertebra (Fig. 2) at 11.45 A. M., with very little bleeding. 3 P. M., attitude entirely normal; left anterior foot most sensitive (hyperæsthetic) on pinching; no loss of motion in posterior extremities; in jumping, he uses all his limbs equally well; sensation in posterior extremities seems to be equally diminished; right pupil contracted.

Expt. 25.—Large rabbit: etherized; tracheotomy. Section of right posterior column with portion of right lateral column and gray matter under second cervical vertebra at 11.45 P. M., without hemorrhage. 3.30 P. M., there does not seem to be any motor paralysis, although the co-ordination in the posterior extremities seems to be a little disturbed; the left leg appears to be moved with difficulty, and the animal leans to that side; there is almost absolute loss of sensation in the left hind leg; sensation normal in fore legs.

Fig. 1.

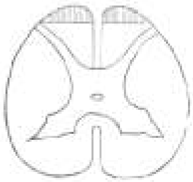
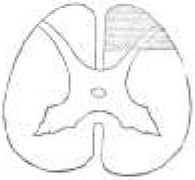


Fig. 2.



Expt. 12.—Medium-sized rabbit: etherized; tracheotomy. Section of posterior column, part of gray matter and part of the lateral columns under second cervical vertebra; no disturbance of respiration at 11.45 A.M.; considerable hemorrhage 3.30 P.M. The only effect appears to be marked want of co-ordination; the animal is unable to make any progression; it appears hyperæsthetic all over the body; when the root of the tail is pinched there is a spasmodic contraction of all the erector spinal muscles; when its nose is irritated it makes violent movements in all the limbs.

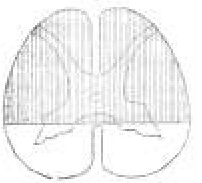
Anterior columns.—The anterior columns have been supposed to preside over movements of flexion (Bellingeri, Valentin); over movements of extension (Budge, Harless, Englehardt); over both movement and sensibility (Meckel, Schœps, Rolando, Calmeil, Jobert); exclusively over sensibility (Walker); exclusively over movement (Ch. Bell, Backer, Longet, Van Deen); more over movement than sensibility (Magendie, Seubert); over peristaltic contractions of the abdominal viscera (Valentin); and when associated with gray matter over both motion and sensation (Van Deen).

Antero-lateral columns are at present almost generally believed to be conductors of voluntary motor impulses (Brown-Séquard, Vulpian, Schiff), while in the dorsal region the motor fibres are supposed mainly to lie in the anterior columns and in the cervical region in the lateral columns (Brown-Séquard, Vulpian), while Brown-Séquard also believes that the antero-lateral regions contain a few sensory fibres.

The lateral columns were held by Bell to be the path of the sensory nerves of respiration, an opinion which is accepted by Schiff, though by him it is confined to the cervical region. They were supposed by Türck to contain the paths of sensation, and have been proved by Woroschiloff in the lumbar region of the rabbit to contain all the motor and sensory fibres and by Miescher, Nawroċki, and Dittmar to contain all the sensory and efferent vaso-motor fibres of the cord.

Our experiments show that neither motor nor sensory fibres run in the anterior columns, for when the entire cord, with the exception of the anterior columns is divided, the animal is entirely paralyzed and insensible in all parts below the section. The following experiment shows this:—

Fig. 3.

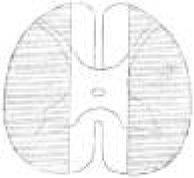


Expt. 18. Large rabbit: etherized; tracheotomy. Section of entire cord, except the anterior columns under the second cervical vertebra (Fig. 3); at 12.30 P. M., some bleeding occurred but was checked by artificial respiration; on section, respiration ceased, so artificial respiration was kept up; 3 P. M., irritating left hind leg with a weak current causes movements in that leg; with stronger currents movements are caused in opposite hind legs and then in fore legs, but none in the head. The animal is apparently entirely paralyzed; irritating the ears causes movements in the head but none in the limbs; no voluntary movements exist; medulla oblongata divided; its irritation with induction current causes no movement.

Although this experiment shows that neither motor nor sensory fibres run in the anterior columns in the cervical region, it does not disclose their function. It is probable on anatomical grounds (Schrœder) that they consist of longitudinal commissural fibres.

It being proved by the above experiment that neither motor nor sensory fibres run in the anterior columns in the cervical region, the following experiment was made to determine whether they ran through the lateral columns:—

Fig. 4.

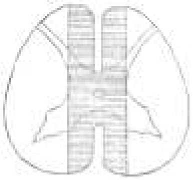


Expt. 21.—Small rabbit: etherized; tracheotomy. Section of both lateral columns under second cervical vertebra (Fig. 4) without hemorrhage; at 11 A. M., respiration ceased, artificial respiration kept up; at 4 P. M., entire paralysis and loss of sensation in all limbs; reflex action present; cord divided; its irritation with electricity produced no movement in the limbs below section.

This experiment in which the gray matter, with the exception of a portion of the cornua, was left intact as well as the anterior and posterior columns, while furnishing additional proof that neither motor nor sensory fibres run through the anterior or posterior columns, also shows the falsity of the opinion held by so many observers (Bellingeri, Calmeil, Schiff, Brown-Séquard, Vulpian) that the gray matter alone of the cord is capable of conducting sensory impressions to the brain, or as some have held, both motor and sensory impressions (Van Deen, Kürschner, Stilling, Calmeil).

This position is further strengthened by the following experiment, the converse of the above, in which the gray matter, as well as the anterior and posterior columns, is divided without loss of sensation or motion, the only effect being marked inco-ordination.

Fig. 5.



Expt. 8.—Medium-sized female rabbit: etherized; tracheotomy. Section of gray matter under fourth cervical vertebra (Fig. 5) at 11 A. M.; respiration not interfered with; animal lies on its side and is unable to get up; irritating ears with electricity causes powerful co-ordinate movements in posterior extremities; sensation appears normal in all limbs; irritating posterior extremities causes movement in head; medulla divided and irritation causes co-ordinate jumping movements in hind leg.

Decussation of Afferent and Efferent Impulse.—From the experiments above quoted it has been shown that in the cervical region of the spinal cord the lateral columns form the ordinary paths of conduction between the brain and the gray matter in connection with the roots of the spinal nerves, while it may be inferred that the gray matter serves essentially for the propagation of reflexes from one spinal level to another. These views are entirely in accordance with our anatomical knowledge of the cord. For since the lateral columns increase in area from below upwards much more steadily than either the gray matter or the anterior or posterior columns, it naturally suggests the view that they are the chief paths through which the brain is brought into connection with the several segments of the cord, and thus with the nerves of the body at large, while we also find that the entrance of any large body of nerves into the cord is associated with a large development of gray matter for the local co-ordinating mechanisms (lumbar and cervical enlargements).

The question now arises, are the afferent and efferent impulses conducted directly in the cord or in a crossed manner. As regards the decussation of motor fibres, Van Kempen, Brown-Séquard, and Schiff, held that there was a partial crossing in the cervical region, and in the other portions a direct conduction, while Vulpian and Woroschiloff believe that there is a partial crossing throughout the entire extent of the cord.

As regards the paths of sensation, Van Deen, Stilling, Brown-Séquard, Türck, and Woroschiloff, believe there is a complete crossing throughout the entire cord, Vulpian that it occurs only to a slight extent, while Chauveau, Von Bezold, and Oré, deny any sensory decussation. Miescher, in studying the paths of the afferent vaso-motor fibres, which are probably identical with sensory nerves, found that the fibres from one sensory nerve (sciatic) passed up both sides of the cord, but that they passed more on the opposite than the same side. The following experiments show the results we obtained in this connection.

Hemisection. Expt. 7.—Large rabbit: etherized; tracheotomy. Hemisection of cord (*left*) under the fourth cervical vertebra, at 12 M., without hemorrhage. Artificial respiration kept up for fifteen minutes, when the animal breathed naturally, the right side possibly being moved more than the left. 4 P. M., animal lies on its left side and is unable to turn over, makes very violent attempts. Upon pinching the nose it moves only the limbs on the right side; sensation appears to be most marked on the right side, though it is present to a considerable degree in all the limbs; the left anterior extremity is paralyzed, left posterior extremity has diminished motion, electro-sensibility seems everywhere about the same; medulla oblongata divided and irritated, causing co-ordinated jumping movements in the posterior extremities, more violent on the right side; rigidity of right anterior extremity. As the cord lost its irritability, motion first disappeared in the left anterior extremity, then in the left posterior extremity, then in right posterior extremity, and finally in the right anterior extremity.

Expt. 20.—Medium-sized rabbit: etherized; tracheotomy. Right hemisection of the cord under the second cervical vertebra at 12.20 P. M., without hemorrhage. 5 P. M., vaso-motor dilatation of the right ear very marked, right pupil smaller; both posterior extremities hyperæsthetic; sensation diminished equally in the anterior extremities; no voluntary motion in the left anterior extremity; motor power very much reduced in both posterior extremities, but is almost absent in the right posterior extremity; reflex activity marked; under ether sensibility disappears first in left limb; medulla oblongata divided; weak induction currents cause movements in both hind legs; more marked on left side; stronger currents arrested motion in right posterior extremity, while it became stronger in the left limb, and even after removal of the stimulus there occurred a number of alternate flexions and extensions of the left posterior extremity.

Section of One Lateral Column. Expt. 11.—Medium-sized rabbit: etherized, tracheotomy. Right lateral column divided between the second and third cervical vertebra (Fig. 6), at 11 A. M.; a little blood was lost in the operation. At the time of section respiration was arrested on one side. 4 P. M., vascular dilatation most marked in the right ear. Right pupil more contracted; hyperæsthesia on the right side; sensation diminished in left posterior extremity; diminished power in posterior extremity, especially in the right; unable to maintain an erect position; irritation of the nose causes movements in both posterior extremities, more marked, however, in the left. Medulla divided, its irritation caused rhythmical movements in both posterior extremities, especially in the left.

Fig. 6.

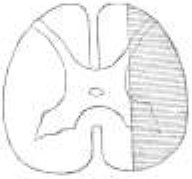


Fig. 7.

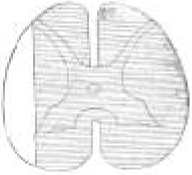
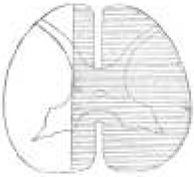


Fig. 8.



Expt. 19.—Large male rabbit: etherized; tracheotomy. Section of the right lateral column under the second cervical vertebra at 11.30 A. M., respiration weaker on the right side at 4 P. M. Sensation impaired in the left hind leg; hyperæsthesia in the right posterior extremity; sensation in left posterior extremity almost absent; sensibility more marked in the right posterior extremity; motion more marked in the left posterior extremity; twitching disappeared; animal eats an apple; left posterior extremity more sensitive to electric stimulation than the right. 4 P. M., medulla divided and irritated when movement ensues in the left limbs, very slight in the right, but co-ordinated jumping-like movements take place.

Section of Entire Cord except one Lateral Column. Expt. 26.—Medium-sized rabbit: etherized; tracheotomy. Whole cord divided except the left lateral column under the second cervical vertebra (Fig. 7) at 12.30 P.M.; artificial respiration necessary till 3.45 P.M.; some sensibility in all the limbs. When the nose is irritated, the left posterior extremity only is moved; when the medulla is divided and the cord is irritated, there is extension of the right fore limbs and tetanic flexion of the left, while the right posterior extremity is flexed on the trunk and the left extended in tetanus.

Expt. 29.—Very small rabbit: etherized; tracheotomy. Cord exposed without hemorrhage; section of entire cord except left lateral column, and a very small quantity of gray matter under the second cervical vertebræ (Fig. 8), at 11.53 A.M., without bleeding; respiration ceased on the side of section, 4 P.M.; right ear the most sensitive; on irritating the nose, the animal moves both posterior extremities, the left much more than the right; it also has slight motor power in the left anterior extremity. When the right hind leg is irritated with electricity, coil at 12 cm., motion is caused in the head; irritation of left hind leg only causes movement of head when the coil is at 0; right anterior extremity most sensitive.

From these experiments it is seen that after *hemisection* of the cord sensation is present in all parts behind the section. When the division is made under the fourth cervical vertebræ, hyperæsthesia occurs on the opposite side, and not on the side of section as claimed by Schiff, Brown-

Séquard, etc., while, when the division is practised under the second cervical vertebræ, it appears on both sides, but more marked on side of section. After hemisection, motor power is reduced in both posterior extremities, more marked on the side of section, and, when the division is made under the fourth cervical vertebræ, the fore limb on that side is paralyzed, since the section destroys the portion of the cord from which part of the nerves to the anterior extremity arise. The pupil is contracted on the side of section, and there is vaso-motor paralysis of the ear and weakened respiration on the same side.

When all except one *lateral column* is divided, the ear on that side of section is most sensitive; there is vaso-motor paralysis of ear and contracted pupil on same side. Hyperæsthesia occurs in the posterior extremities on the side of section, with diminished sensibility on the opposite side; motor power is diminished in all the limbs, though there is a more marked loss on the side of section; respiration is arrested on the side of section.

It may be concluded, therefore, that there is a partial crossing of both sensory and motor fibres in the cervical portion of the cord in the rabbit, and that there is a greater decussation of sensory fibres than of motor.

The section of a lateral column was followed by hyperæsthesia on that side, thus agreeing with the statement of Woroschiloff, that fibres administering to hyperæsthesia run in that column.

From thirty experiments on rabbits, all of which furnished results in accordance with the examples we have given, we draw the following conclusions:—

1. That the motor and sensory fibres in the cervical segment of the spinal cord run exclusively in the lateral columns.
2. That the nerves administering to respiration, vaso-motor nerves, and cilio-spinal nerves also run in the lateral columns.
3. That the posterior columns are concerned in co-ordination.
4. That irritation of the cervical cord causes co-ordinated jumping movements.
5. That no sensory fibres pass to the brain in the posterior columns.

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ARTICLE IX.

OBSERVATIONS ON INFILTRATION OF THE RETINA IN LARDACEOUS DISEASE OF THE KIDNEYS DUE TO CHRONIC SUPPURATION FROM BONE DISEASE.

By CHARLES STEDMAN BULL, A.M., M.D., Surgeon to the New York Eye Infirmary.

THE connection between a certain variety of retinitis and chronic renal disease, and that between the latter and chronic suppuration from bone